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Chemical Mixing in an Aquifer

Chemicals leaching through soils to groundwater mix with water already present there. The change in concentration of the chemical depends upon the concentration of the solution entering the aquifer (the inflow concentration), the rate at which the solution is entering the aquifer (the recharge rate), the initial concentration of water in the aquifer (the initial concentration), and the amount of water in the aquifer (the product of the porosity and thickness of the aquifer). This software allows a user to modify these parameters and to observe the aquifer concentration as a function of time. The total time required to reach a critical concentration is also displayed. The software is based on a model of a simplified aquifer system.

Model Description

Consider a steady-flow system. The mass balance equation describing the time variation of average concentration in an aquifer under constant recharge from the surface soil can be written as (Appelo and Postma, 1993; Gelhar, 1993)

$$nH\frac{\partial C}{\partial t} = -q(C - C_{in})$$

where n is the effective porosity of the aquifer, H is the average thickness of the aquifer, C is the average concentration in the aquifer, q is the flux density of water entering the aquifer or the aquifer recharge rate , C_{in} is the inflow concentration, and t is time. Solving the differential equation above for an initial concentration of C_0 yields

$$C(t) = C_0\, e^{-qt/nH} + C_{in}\left(1 - e^{-qt/nH}\right)$$

where C(t) is the average concentration in the aquifer at time t.

Assumptions and Simplifications

1. The aquifer is viewed as a ideal mixer or a constantly stirred tank.
2. Water enters the aquifer at a constant recharge rate , q, and constant concentration C_{in} .
3. Discharge from the aquifer is equal to the recharge and the aquifer is a steady-flow system.

Some of these simplifications have been removed in the numerical solutions to this problem included in the AquiferMixing spreadsheet (6.6 MB, Microsoft Excel required)

Glossary

Aquifer recharge rate: The recharge rate of the aquifer is the volume of water entering the aquifer per unit cross-sectional area per unit time.

Critical concentration: The maximum acceptable concentration of the chemical in the aquifer such as the HAL or MCL of the chemical.

Flux density: The volume of water flowing per unit cross-sectional area per unit time is known as the flux density of water.

Ideal mixer: An ideal mixer refers to a hypothetical flow system in which the outflow concentration is equal to the average concentration in the system.

Steady-flow groundwater reservoir: A steady-flow groundwater reservoir refers to an aquifer system whose recharge and discharge rates are equal.

Bibliography

Appelo, C. A. J. and D. Postma, 1993. Geochemistry, groundwater and pollution, p. 315-318.

Gelhar, L. W., 1993. Stochastic subsurface hydrology, p. 63-93. Prentice-Hall, Inc., A Simon & Schuster Company, Englewood Cliffs, New Jersey 07632.

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